Communications

Electronic Collision Frequency in the F Region at Sunrise & Sunset

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The variation of the effective collision frequency of electrons ν_{eff} with solar zenith angle χ has been studied around sunrise and sunset by group retardation method [Appleton, E. V., *Nature, Lond.*, **135**(1935), 618] at different radio frequencies. The variation is found to be steeper at sunrise than at sunset. Taking a linear relationship between ν_{eff} and f^2, the square of radio frequency, a rough estimate of the electron temperature T_e has been made. The resulting values of T_e at sunrise and sunset are found to be 1113 and 987 °K, respectively.

During Sep. and Oct. 1972 ν_{eff} for ordinary mode was measured at sunrise and sunset, using the group retardation technique of Appleton.[1] Measurements were made at Delhi (lat., 28°38'N; long., 77°13'E) with a variable frequency ionosonde available with the Delhi University. Experimental set-up and the method of analysis are described in an earlier paper by Setty *et al.*[2] However, from the ionograms, taken manually before and after the amplitude group height records, true heights have been derived using the polynomial method of Titheridge.[3]

Fig. 1 shows the variations of ν_{eff} with χ. A straight line has been fitted by the method of least squares. Fig. 1 shows that ν_{eff} increases at a faster rate as the sun comes up, i.e. $100° \geqslant \chi \geqslant 90°$ than the rate at which it decreases after sunset, i.e $90° \lesssim \chi \lesssim 110°$. The most probable values of ν_{eff} lie between $(3{\cdot}5-4{\cdot}5) \times 10^3\ sec^{-1}$ for wave frequencies between 8 and 11 MHz, which are close to the ν_{eff} values reported by Setty *et al.*[2] near sunrise during equinox period.

A rough estimate of T_e has been made from the linear relationship between ν_{eff} and f^2 represented by the formula[4]

$$\nu_{eff} = \nu_{en} + \nu_{ei}$$

$$= \sigma(O) . N(O) . T_e^{1/2} + 4{\cdot}7 \times 10^4 . T_e^{-3/2} . f^2$$

where ν_{en} and ν_{ei} are the collision frequencies of electrons with neutral species and with ions respectively, σ (O) is the reduced collision cross-section and N (O) is the concentration of atomic exygen at the reflection height.

Fig. 2 shows the variation of ν_{eff} with f^2. From the slope of the plots T_e was computed. It is found

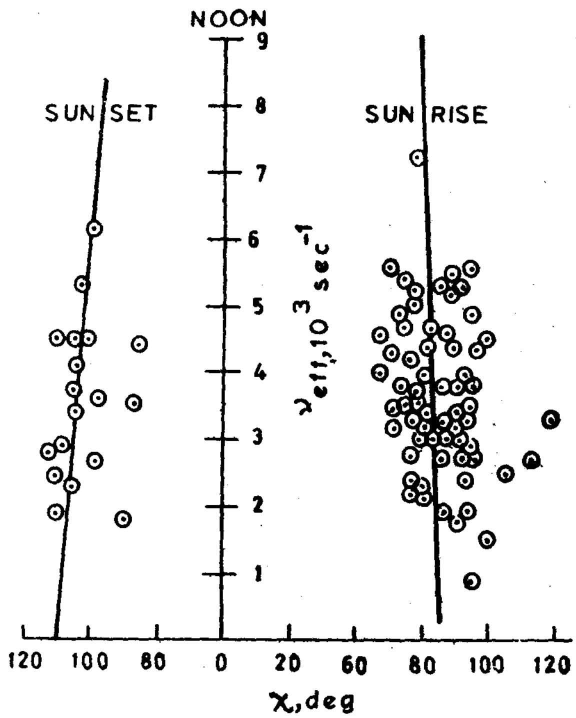

Fig. 1—Variation of collision frequency with solar zenith angle (χ) near sunrise and sunset

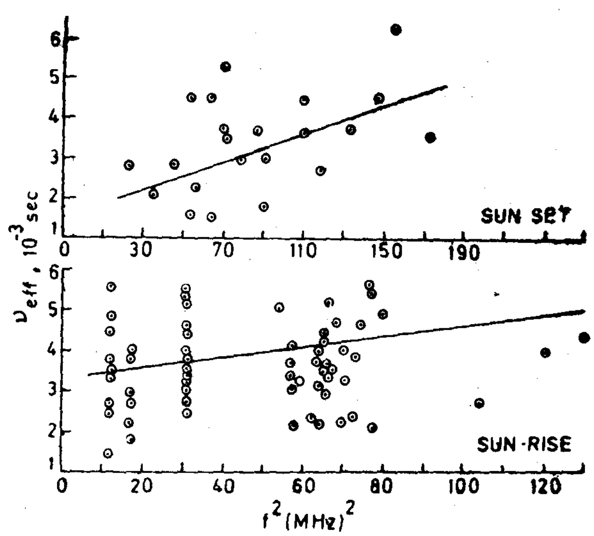

Fig. 2 – Variation of collision frequency with the square of radio frequency near sunrise rnd sunset

to be 1131°K near sunrise and 987°K near sunset. The departure of these temperatures from the neutral gas temperature at the altitude of 250 km (CIRA, 1965) is found to be approximately 200°K. This departure at noon was found to lie between 800 to 1500°K by Dalgarno *et al.*[5]

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Non-linear Interaction of Electromagnetic Waves in the Ionosphere

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Non-linear interaction of electromagnetic waves within the ionosphere has been investigated theoretically using derivative expansion technique. The shifts in frequency and wave-number are seen to increase when the medium is excited with waves of more than one frequency unlike the situation reported by Nayfeh [*Phys. Fluids*, 8 (1965), 1896]. Possible regions of interaction are being studied through numerical computations.

The phenomena of non-linear interaction of high frequency electromagnetic waves within laboratory plasma and ionospheric plasma have been widely investigated theoretically and experimentally by several authors.[1-5] In thermal equilibrium or fairly close to equilibrium, the interaction within the ionosphere is extremely weak and is due merely to the thermal fluctuations in electron number density. But in the equatorial E-region for instance this interaction is comparatively stronger (although still weak so that Born approximation applies). This is due to electron number density fluctuation associated with the equatorial electrojet. The theory of two-stream instability of Dougherty and Farley[6] is generally utilized to explain the effects of such interactions. But the theory is not adequate to interpret all the observed results from such regions of the ionosphere. This is due to the additional dissipative processes like thermal conduction, streaming of charged particles and non-linear effects because of electrostatic as well as electromagnetic interaction that have not been included in the theory. In the present analysis, the derivative-expansion technique is used to study such a situation and to investigate the non-linear interaction between two electromagnetic waves as well as to determine the higher-order variables during the excitation of the stated medium with two incident waves. The results can be tested for the E-region of the ionosphere with appropriate physical parameters.

The excitation of the plasma with two incident waves can be represented as

$$E_1 = (A_1 e^{i\psi_1} + A_1^* e^{-i\psi_1}) + (A_2 e^{i\psi_2} + A_2^* e^{-i\psi_2}) \qquad \ldots(1)$$

where

$$\psi_1 = k_1 z_0 - \omega_1 t_0, \; \psi_2 = k_2 z_0 - \omega_2 t_0$$

and the other symbols have their usual significance.

Nayfeh's equations under the stated circumstances yield expressions for second and higher order variables. Thus the expression for E_2 can be written as

$$E_2 = a_1 (A_1^2 e^{i2\psi} - A_1^{*2} e^{-i2\psi_1})$$

$$+ a_2 (A_2^2 e^{i2\psi_2} - A_2^{*2} e^{-i2\psi_2})$$

$$+ b_1 (A_1 A_2 e^{i\psi_+} - A_1^* A_2^* e^{-i\psi_+})$$

$$+ b_2 (A_1 A_2^* e^{i\psi_-} - A_1^* A_2 e^{-i\psi_-}) \qquad \ldots(2)$$

where

$$a_{1,2} = -\frac{ik_{1,2}}{12\pi N_0 e \, \omega_p^2} (3\omega_p^2 + 4U_e^2 k^2{}_{,2})$$

$$b_{1,2} = -\frac{ik_\pm (h_{1,2} + 2U_e^2 k_1 k_2)}{4\pi N_0 e (h_{1,2} - 2U_e^2 k_1 k_2)}$$

$$h_{1,2} = 2\omega_1\omega_2 \pm \omega_p^2, \; k_\pm = k_1 \pm k_2$$

$$\omega_p^2 = \frac{4\pi_0 N_0 e^2}{m}, \; U_e^2 = \frac{3p_0}{m_e N_0}, \; \psi_\pm = \psi_1 \pm \psi_2$$

Introducing the results for the first and second orders, the higher order variables can be calculated.